PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01S 1/02, 5/14

A1

(11) International Publication Number: **WO 00/58744**

(43) International Publication Date: 5 October 2000 (05.10.00)

(21) International Application Number: PCT/GB00/01145

(22) International Filing Date: 24 March 2000 (24.03.00)

(30) Priority Data:
9907123.5 26 March 1999 (26.03.99) GB

(71) Applicant *(for all designated States except US)*: POINTSTAR A/S [DK/DK]; Ellegardevej 36, DK–6400 Sonderborg (DK).

(72) Inventor; and

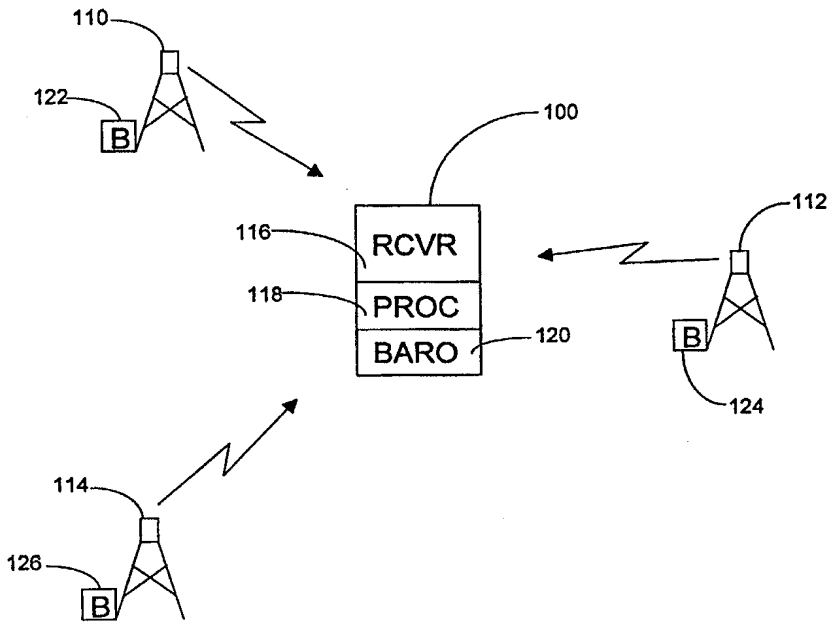
(75) Inventor/Applicant *(for US only)*: BIDE, Stephen [GB/DK]; Torvet 9, DK–6100 Haderslev (DK).

(74) Agents: HOGG, Jeffrey, Keith et al.; Withers & Rogers, GOLDING HOUSE, 2 Hays Lane, London SE1 2HW (GB).

(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: POSITION FINDING



(57) Abstract

A locator (100) receives signals from at least one beacon (110, 112 and 114). At least one beacon has a barometer (122, 124 and 126) for measuring local air pressure. The air pressure information is transmitted by the beacons with the position finding signals. The locator (100) uses the local air pressure information to calibrate its barometer (120). The barometer (120) may be used to measure the altitude of the locator (100).

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

POSITION FINDING

This application relates to position finding and locator apparatus. In particular, this application relates to locator apparatus comprising receiver means which determines position using wireless signals from beacons.

A known position finding method (US Pat. Nos. 5646857 & 5210540) relies on the augmentation of the Global Positioning System (GPS) satellite-based radio beacon system by coupling a barometric altimeter to the earth-based GPS receiver.

A terrestrial GPS receiver can determine its 3D position by reference to signals received passively from a network of suitably spaced geostationary satellites. However, a GPS receiver can only receive from those satellites which are in line of sight and furthermore requires signals from at least four satellites at once in order to perform accurate 3D position finding. The GPS system can therefore easily be compromised in e.g. covered, built-up or heavily foliated areas, where a receiver does not have line of sight to a requisite number of satellites. GPS reliability is even substantially reduced by bad weather conditions, and GPS accuracy is in any case deliberately degraded in connection with civilian use.

The addition of an accurate barometric altimeter could in principle augment satellite derived position co-ordinates with an altitude co-ordinate derived from a different source, thereby theoretically reducing the number of simultaneous satellite signals required for 3D positioning.

However, in order to work effectively the barometric altimeter requires continuous calibration to allow for local terrestrial weather-dependent air-pressure conditions. Reference data for this purpose can only be supplied from a network of local terrestrial air-pressure monitoring stations spaced at relatively close intervals. Being positioned in space, the GPS system makes no provision for either the collection or dissemination of such data.

A terrestrial radio beacon system, on the other hand, suffers by definition from being arrayed in one plane i.e. on the earth's surface, and thereby only being able to provide positioning in 2 dimensions. Furthermore, the earth's natural curvature inhibits useful reception at long range preventing even this level of functionality unless the beacons are very closely spaced. Under normal circumstances the deployment of such a closely-spaced terrestrial beacon system world-wide would be both prohibitively expensive and politically unfeasible.

It is an aim of the present invention to remedy the current inherent inadequacies of barometric altimeter augmented position finding by combining the positioning data broadcast by beacons with locally-derived air-pressure reference data derived from reference barometric sensors.

According to a first aspect, the invention relates to a method of determining the position of a locator apparatus using one or more beacons that transmit wireless signals, the method comprising the steps of providing the locator apparatus with receiver means to receive signals from the beacons, determining the position of the locator apparatus using signals from said beacons and determining the height or altitude of the locator apparatus using a barometer means which is calibrated using barometric information included in signals from said beacons.

According to a second aspect, the invention consists in locator apparatus comprising receiver means for receiving wireless signals from beacons, barometer means and processing means for determining the position of the locator apparatus from the signals and for extracting barometric information from the signals and using it to calibrate the barometer means. Preferably, the processing means uses barometric information from the barometer means to determine the altitude, vertical position or height of the locator device.

According to a third aspect, the invention consists in a beacon of known 3D position (latitude, longitude and altitude) arranged to transmit a signal, which can be used by a receiver to determine its position and which is combined with barometric information about the locality of the beacon for calibration of a barometer at the receiver.

Advantageously, the beacon has barometer means for determining, or storage means for storing, barometric information about its locality.

According to one embodiment, the present invention avoids reliance on satellites for positioning, and instead makes possible an effective 3D implementation of terrestrially originated 2D signals, preferably employing a network of closely spaced transmitters which utilise RF signal carrier types which are less affected by obstructions in the environment (such as the digital audio broadcasting - DAB - system), permitting more efficient position finding in, eg., built-up urban environments, poor weather and even within buildings.

According to another embodiment, the system is employed to supplement a satellite-based positioning system (like GPS) by transmitting local barometric reference data to satellites, which could then in turn be retransmitted to terrestrial positioning receivers with the positioning signal.

Further aspects and advantages of the invention will be apparent to a person skilled in this art upon consideration of the following embodiments of the invention which are described by way of example only and with reference to the following drawing, Figure 1, which illustrates schematically a location finding system.

Figure 1 shows a location finding system comprising a locator device 100 and a network of ground based transmitters, three of which are shown: 110, 112 and 114.

The locator device 100 comprises a receiver 116, a processor 118 and a barometer 120. The receiver 116 receives the signals from those transmitters 110, 112 and 114 which are within range and the processor 118 uses the received wireless signals, which are preferably radio or microwave frequency signals, to deduce the position of the locator device relative to the transmitters. For example, the processor 118 could establish the two-dimensional position of the locator device by triangulating using signals from at least three of the transmitters 110, 112 and 114 in the transmitter network. The receiver 116 also receives barometric information which is transmitted from the transmitters in the network as part of

the positioning signals. The processor 118 uses this barometric information to determine the vertical position of the locator device as will be described later.

At least some of the transmitters in the network are of known altitude (as ascertained from, e.g., survey data) and are capable of transmitting barometric information comprising the air pressure in the locality of the transmitter. (In another embodiment, to provide finer geographical resolution of air pressure variation, all of the transmitters in the network are of known altitude and are capable of transmitting barometric information comprising the air pressure in their locality.) To do this, a transmitter, eg. 110, can be provided with a barometer 122 which provides accurate barometric information for encoding and transmission by the transmitter 110 as part of the signal intended for use in position finding. Alternatively, the barometric information could be provided to the transmitter from a memory device which stores the current or most recent value of the air pressure in the locality of the transmitter. The barometric information in the memory device at a transmitter site could itself be supplemented, checked and enhanced by comparison with barometric information from neighbouring sites by monitoring the signals from neighbouring sites. In Figure 1, each of the three illustrated network transmitters 110, 112 and 114, is of known altitude, has its own respective local barometer 122, 124 and 126, and is therefore capable of transmitting barometric calibration information regarding its own locality.

Returning to the locator device 100, the processor 118 uses its local air pressure as measured by the integral barometer 120 to determine the vertical position of the locator device 100 in a known manner. In order to ensure accurate vertical position measurements, the integral barometer 120 is calibrated using the barometric information received from transmitters in the network. If the locator device 100 receives barometric information from more than one transmitter, then it could determine the barometric data for use in the calibration process by calculating which of the transmitters broadcasting barometric information is nearest and using the barometric information from that transmitter, or it could determine the barometric information for use in the calibration process by performing a weighted average of the barometric information received from several

transmitters by assigning weights on the basis of the distance to those transmitters from which barometric information is being received.

It will be appreciated that the numbers of transmitters and locator devices shown in Figure 1 are not limiting. More than one locator device can operate within the network of transmitters and the network would ideally comprise far more than the three transmitters shown.

In an alternative embodiment, the locator device 100 does not need to receive signals from more than one transmitter. For example, the locator device could be used to follow a "beam" broadcast by a beacon, the beacon signal also containing barometric information. In this embodiment, the locator device would use the barometric information contained in the beacon signal to calibrate the integral barometer for vertical position measurements when following the transmitter "beam".

It will be appreciated that the locator device has utility in various scenarios. The locator device could be provided as a hand held unit to assist persons engaged in outdoor activities or it could be installed in any kind of vehicle.

In a further embodiment, the locator device includes a transmitter for return transmission of information about its position to a central station or to mobile peer locator devices for tracking purposes. The same network of transmitters could be employed for transmitting the position information to its destination.

Claims

1. A method of determining the position of a locator apparatus using one or more beacons that transmit wireless signals, the method comprising the steps of providing the locator apparatus with receiver means to receive signals from the beacon(s), determining the position of the locator apparatus using signals from said beacon(s) and determining the height or altitude of the locator apparatus using a barometer means which is calibrated using barometric information included in signals from said beacon(s).

2. A method according to claim 1, comprising the step of using signals from more than one beacon to calibrate the barometer means.

3. A method according to claim 1 or 2, comprising the step of transmitting the determined position of the locator device to a receiver.

4. Locator apparatus comprising receiver means for receiving wireless signals from beacons, barometer means for determining the height or altitude of the locator apparatus and processing means for determining the position of the locator apparatus from the signals and for extracting barometric information from the signals and using it to calibrate the barometer means.

5. Apparatus according to claim 4, wherein the processor means is arranged to calibrate the barometer means using signals from more than one beacon.

6. Apparatus according to claim 4 or 5, further comprising a transmitter to transmit the determined position of the apparatus to a receiver.

7. A beacon of known position arranged to transmit a signal, which can be used by a receiver to determine its position and which is combined with barometric information about the locality of the beacon for calibration of a barometer at the receiver.

8. A beacon according to claim 7, further comprising a barometer means for determining barometric information about its locality.

9. A beacon according to claim 7 or 8, comprising storage means for storing barometric information about its locality.

10. A beacon according to claim 7, comprising storage means for storing barometric information about a locality.

11. A beacon according to claim 7 or 10, wherein the beacon is a satellite.

12. A position finding system comprising at least one locator apparatus according to any one of claims 4 to 6 and at least one beacon according to any one of claims 7 to 11.

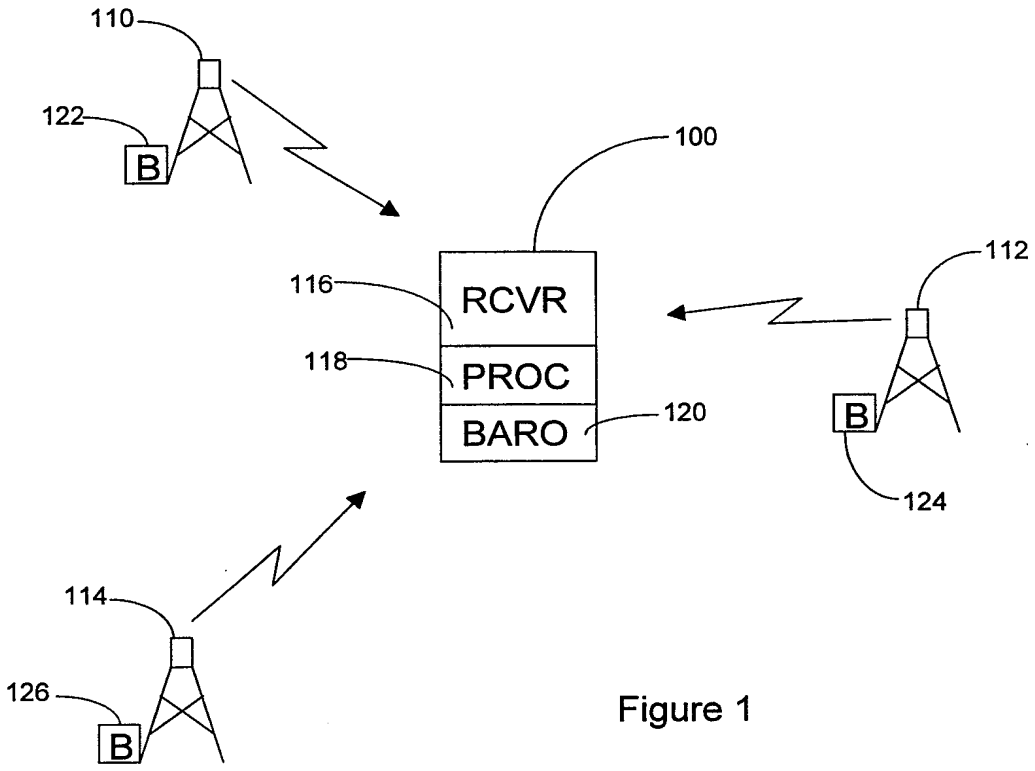


Figure 1

INTERNATIONAL SEARCH REPORT

Int. ational Application No
PCT/GB 00/01145

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S1/02 G01S5/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01S G01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 210 540 A (MASUMOTO YUTAKA) 11 May 1993 (1993-05-11) cited in the application * 2nd Embodiment *	1-12
A	WO 98 43045 A (HEDRICK GEOFFREY S M) 1 October 1998 (1998-10-01) * Detailed Description of the presently preferred Embodiments * abstract	1-12
A	DE 195 01 879 A (SEXTANT AVIONIQUE) 25 July 1996 (1996-07-25) claim 5	1

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 June 2000	03/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Ó Donnabháin, C

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Int. .tional Application No
PCT/GB 00/01145

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 646 857 A (BRAISTED PAUL ET AL) 8 July 1997 (1997-07-08) * Summary of the Invention * column 11, line 56 -column 12, line 28	1-12
A	US 5 702 070 A (WAID JAMES D) 30 December 1997 (1997-12-30) column 6, line 29 - line 42 column 7, line 7 - line 15 claim 1	1

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. ional Application No
PCT/GB 00/01145

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5210540 A	11-05-1993	JP 4369492 A	22-12-1992
		DE 4219929 A	24-12-1992
		GB 2256987 A,B	23-12-1992
WO 9843045 A	01-10-1998	EP 0974039 A	26-01-2000
		US 5940035 A	17-08-1999
		WO 9843107 A	01-10-1998
DE 19501879 A	25-07-1996	FR 2708349 A	03-02-1995
US 5646857 A	08-07-1997	US 6055477 A	25-04-2000
US 5702070 A	30-12-1997	NONE	